Implementation of a Hybrid Analog/Digital Video Management System

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by: Kenneth L. Salvail, P.E.
City of San Jose Department of Transportation
ITS Operations & Management Section
200 E. Santa Clara Street
San Jose, CA 95113
Phone: (408) 535-3850
Fax: (408) 292-6093

CITY OF SAN JOSE
CAPITAL OF SILICON VALLEY

Abstract

The Silicon-Valley Intelligent Transportation System (SV-ITS) Program is a twelve local-county-state agency partnership that was established in 1995 to jointly develop an intelligent transportation system to cooperatively manage and improve traffic flow within a growing high tech industry area of San Jose, California. A regional networked analog video system was deployed for the partnership to support real time traffic and incident management capabilities. A strategy was developed for sharing each agency's traffic video feeds. An analog video system was determined to be the most viable and stable system to deploy at the time.

The Program completed its initial deployment of an analog video traffic surveillance system in 1998. It included the installation of analog matrix switchers, point-to-point communication between the field and traffic management centers, and video tie lines between these centers. Today, the use of the SV-ITS Program's video system has expanded to support public safety, homeland security and incident management. To more cost effectively disseminate video to these partners, a hybrid video management system concept was adopted. This includes the integration of the analog matrix switchers with digital video servers and distribution of digital video over an upgraded wide area Ethernet network. With this solution, the Program is able to build upon the existing high quality local analog video system, with the newer digital video solutions to improve distribution of 300 video cameras across the region.

This paper includes reasons for adopting a hybrid analog/digital video management system, and how it supports the Program's efforts to integrate local and state agency video systems.

I. The Silicon-Valley ITS Program

In the early 1990's, the City of San Jose embarked on its first effort to explore, deploy, and operate Intelligent Transportation Systems (ITS) in response to the increasing demands placed upon its transportation network. The high tech industry of the Silicon Valley was rapidly growing, with population and traffic congestion following suit. Over 500 traffic signals were interconnected to allow remote traffic flow management of key commute corridors. Traffic surveillance cameras and changeable message signs were installed in its downtown employment and entertainment center to improve travel experience, and ultimately to support the economic vitality of the downtown.

With the successful deployment and use of technology to manage commute and event traffic, the City of San Jose developed a partnership with other local and regional transportation, transit, enforcement, and funding agencies to develop a strategy to manage regional traffic impacts. The Partnership recognized that there would be tremendous value in building ITS in the region, where services would be integrated, resources shared, and interagency relations on all levels strengthened. The Silicon Valley Intelligent Transportation System (SV-ITS) Program was borne, serving as the Northern California's first multi-jurisdictional endeavor to implement integrated traffic management strategies on arterial corridors to improve day-to-day commute travel experience and minimize delay impacts of incident and event related traffic.

Today, the Program's deployment of ITS spans along a total of 25-mile long arterial segments that cut across six local agencies and connects two separate counties as shown in Figure 1. Traffic management centers across the region are connected via fiber optic cables to enable sharing of video and data to keep the freeways, parallel expressways and arterial streets, and transit facilities operating at maximum efficiency. The agencies are able to retrieve necessary data from a common analog video surveillance system, share control of changeable message signs, and view each other's signal timing data to support real time traffic management. Two more phases of infrastructure expansion efforts are planned, increasing inventory of camera feeds, and connections between traffic management centers.

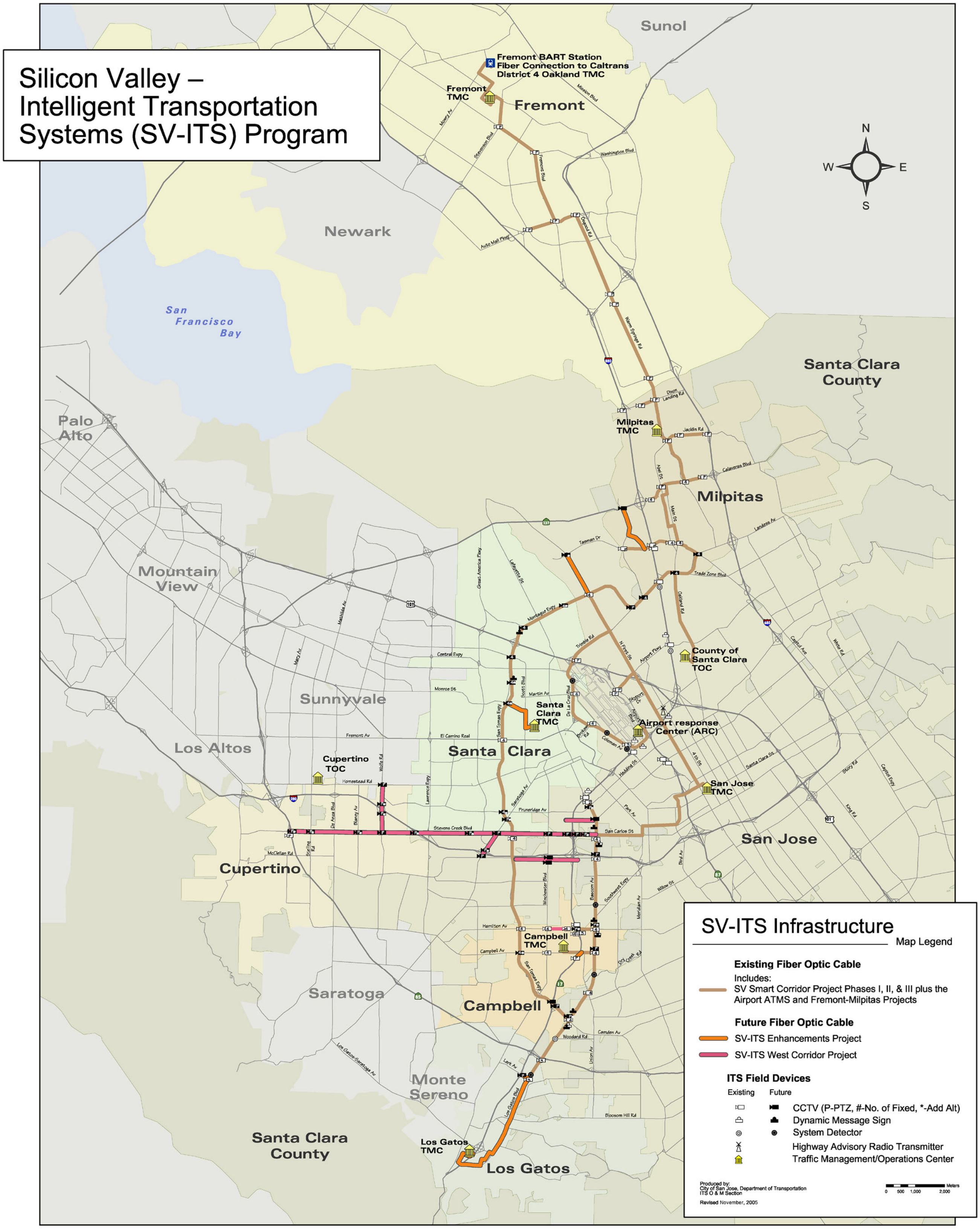

FIGURE 1. SV-ITS Program Infrastructure Map

II. Sharing Video from the Beginning to Now

In 1990, the City of San Jose installed a COHU/Vicon matrix switching system for its traffic surveillance to support real time remote traffic management. This comprised of COHU PTZ cameras equipped with remote COHU controls installed in the field, and a Vicon matrix switcher and a central COHU control system installed back at the traffic management center as shown in Figure 2. Analog camera feeds were connected back to the traffic management center over single mode or multi mode fiber.

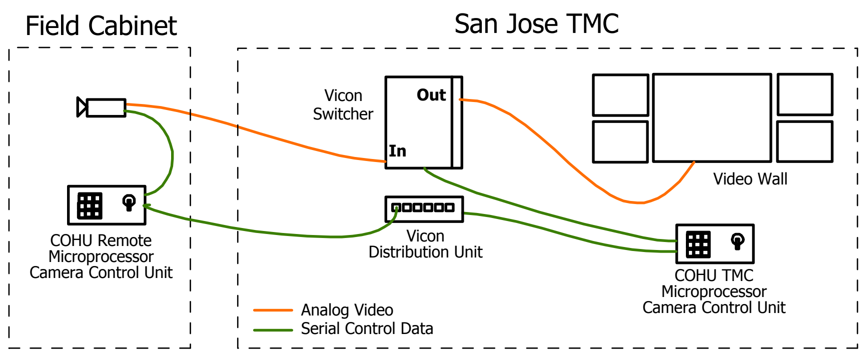

FIGURE 2. COHU/Vicon Control System

The SV-ITS Program began deployment of its first traffic surveillance system in 1997 to allow the sharing of video feeds between four agencies: the County of Santa Clara, and the cities of Campbell, Milpitas, and San Jose. Due to limited funds, the project consultants at the time recommended that an analog switching system be installed at the first two agencies (County, and Campbell), while the third agency (Milpitas) be tied into the County's switcher and the last, San Jose, utilize its existing COHU/Vicon system. This required each agency to interface with three different control units to access its own, and the two other agencies' video feeds. This methodology was taxing on the outside fiber physical plant, because it required two control lines to be dedicated between each agency. The three-control unit operation also became cumbersome to the traffic management center operation staff.

This concept of operation had to change as the SV-ITS Program brought on new partners. Under the existing methodology, each agency would have the number of control device equivalent to the number of partner agencies sharing the video. This obviously did not make practical or fiscal sense. So with the next Program expansion effort, San Jose's COHU/Vicon system was replaced with a Pelco system to be compatible with the other existing switcher systems. A Pelco network interface unit was installed in order to centralize the control of the regions cameras as shown in Figure 3. Video tie lines were recommended based on the need to share video among the neighboring agencies. While this required significant reconfiguration of the outside fiber physical plant, it allowed for more efficient use of the fiber strands and reduced the number of end equipment required. More importantly, it reduced the multiple control unit set up to a single control unit.

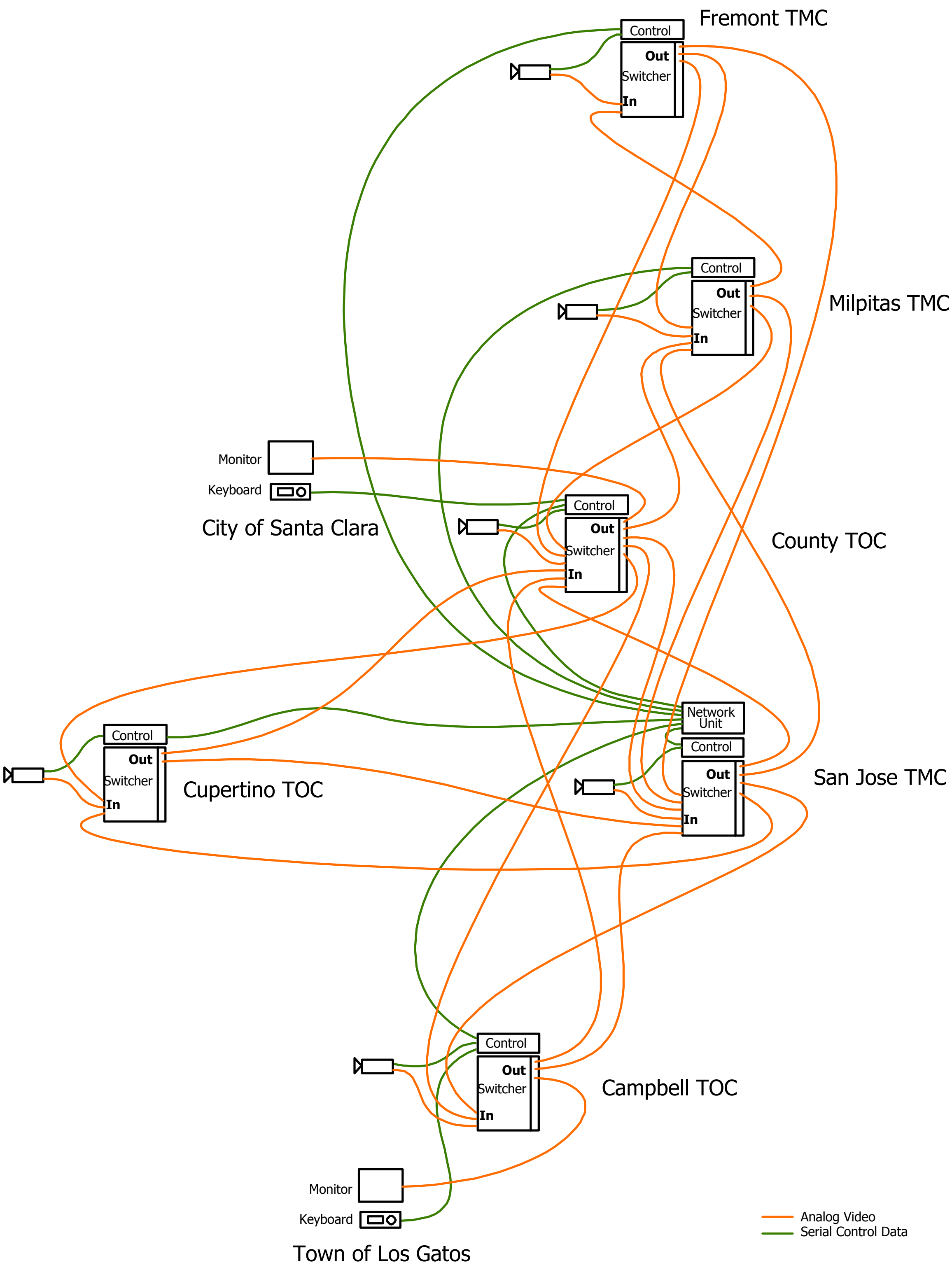

FIGURE 3. Pelco Networked Control System – Existing and Recommended

III. Why Analog Video

At the time of deployment in early 1990's, development of standards for coding analog video had just begun. The first standard, MPEG-1, was established in 1992 and was designed to produce reasonable quality images and at low bit rates. This standard could not provide broadcast quality video like that of an analog system. Therefore, an analog video system was deployed.

When the SV-ITS Program deployed its video system in 1997, the second coding standard, MPEG-2 was established; and was designed to produce broadcast quality images at higher bit rates. The implementation of MPEG-2 would have required a high bandwidth network, which at that time, was determined to be cost prohibitive. In addition, given that an analog video system is designed as a point-to-point topology, it was easier to deploy and is quicker to troubleshoot.

IV. Why a Hybrid Analog/Digital System

There are at least two reasons for adopting a hybrid analog/digital system: 1) to more easily share an existing analog video system, and 2) to expand the field camera inventory without having to upsize existing outside fiber physical plant.

Today, sharing of video has become critical to the safety, security, and operational efficiency of our roadway and critical infrastructure. As such, the public safety entities are tapping into existing video resources where possible. In most cases, transportation agencies already have an established video system that is shared among its transportation partners. A hybrid analog/digital solution allows the sharing of analog video beyond transportation partners to be accomplished easily and cost effectively; especially if there is already a high bandwidth IP network in place. By using the existing network, digital video start-up costs are lower with no significant increase in maintenance cost.

Operational efficiencies often mean "do more with less". Agencies are always looking for ways to improve efficiencies of our people and our systems. Increasing camera inventory to provide greater traffic surveillance coverage allows operation staff to assess conditions quicker and easier, and respond appropriately and swiftly. Deploying an IP network in the field allows more camera feeds to be brought on line over the existing outside fiber physical plant. The coding of analog video at the field cameras can be daisy-chained, like a bus topology; thus, significantly improving the efficient use of the outside fiber physical plant. A side advantage to deploying an IP network in the field is that NTCIP traffic controllers that have higher bandwidth requirements can be brought on-line over the same fiber network.

V. Implementing a Hybrid Analog/Digital System

In order to distribute and provide remote command and control capabilities to other system administrators or operators, an IP component needs to be added to the existing analog system as shown in Figure 4. Analog video needs to be converted to IP video using an encoder. A management server is needed to interface with the analog matrix switcher to select the camera desired, as well as to manage permissions. A remote user would view the camera images on his or her desktop.

Deploying an IP network in the field to bring video feeds back to the control center requires an encoder installed at the camera.

A single interface is desired for controlling both analog and digital systems. In order to view the digital video on the analog wall, the digital video has to be decoded and routed to the analog switcher. To view the analog video on the desktop, the analog video has to be encoded at the switcher and routed to the IP network.

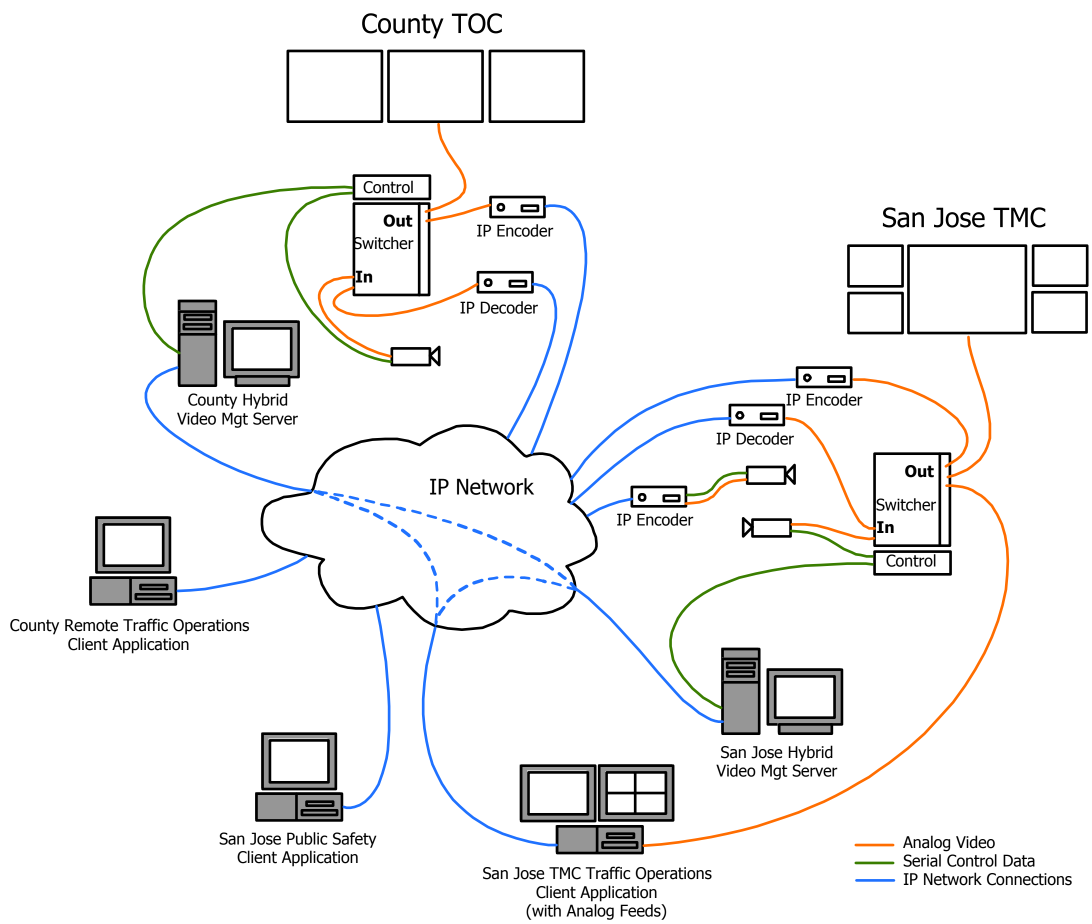

FIGURE 4. Sample Hybrid Analog/Digital Control System between two Agencies

VI. Considerations Before Deploying Digital Video

When deploying digital video, the following issues should be considered:

Hybrid Systems that are not so Hybrid – Beware of the all-digital distribution systems that claim to have good control and command of analog video. Systems utilizing Microsoft® Windows Media® Sever do not work well for command and control due to very long latency. Systems that utilize Motion JPEG do not work well due to the extensive amount of bandwidth required to achieve broadcast quality. From our experience and based on the systems available today, it is recommended that two separate systems be deployed.

It is also important to consider selecting encoders that are capable of dual streaming. This will allow a low quality image to be distributed to travelers, and a broadcast quality image to be accessed by operation staff.

MPEG Standards – MPEG-4 is a decoding standard where there are many different ways to encode the video, as long as it is delivered in a format that can be understood by a compliant MPEG-4 decoder. Consequently, MPEG-4 encoders vary a great deal in image quality. In order to simplify the selection of encoding and decoding equipment, image quality needs to be established. Image resolution and frames per second are key components that need to be considered when establishing image quality.

Encoder/Decoder Compatibility Issues – Even though there are coding standards, decoding of another manufacturers encoded video stream can not be accomplished today. It is recommended that one manufacturers' encoder and decoder devices be deployed, not only to minimize the need to support multiple manufacture equipment, but also to reduce the number of decoding devices needed to decode digital video from the field cameras to the analog switcher.

Software Decoding Issues – Not all software-decoding schemes are created equal. Some manufacture schemes are highly optimized and as such allow several video streams to be decoded at once. There are also nuances related to displaying digital video streams on certain model of video cards and whether it is displayed on the primary or secondary monitor.

PC Issues – The processing power and video card requirements for software decoding needs to be carefully reviewed. PC's are typically involved in a number of tasks simultaneously, and it can take significant processing power to decode the digital video streams. Many manufactures' minimum requirements are generated from an unloaded processor. Yet, in everyday use, the processor is typically loaded with execution of multiple applications. Therefore, PC's may need to be more powerful than the minimum specified by the software decoding manufacturer.

IP Multicasting – IP multicasting allows a single source of video to be viewed concurrently by multiple users. It is designed to provide an efficient way to transmit data using the least amount of network bandwidth. To work, the encoders must be able to transmit multicast IP, and all network switches/routers must support the Internet Group Management Protocol (IGMP) and the edge switches must support IGMP Snooping. Sometimes this can not be achieved across the network. In this case, certain network switches/routers need to be configured to not flood the network, which can quickly bog down the entire network.

IP Network Management – Deployment of digital video utilizes an IP network that requires IT support to ensure that sufficient capacity exists or has been designed appropriately. Continuous management of the IP network will need to be performed as well. Partnering with IT staff earlier, rather than later, is highly recommended.

Field Ethernet Devices - Deployment of digital video also requires the installation of Ethernet devices in the field. Consideration must be given to the extreme temperature and the harsh environments to which these devices will be exposed. Since the Ethernet devices are typically installed in a bus topology, consideration should be given to implementing a redundant path and ring management software.

If no outside fiber physical plant is available, but a traffic signal copper interconnect cable exists, then Ethernet over copper solutions can be implemented, albeit at a modest bandwidth.

VII. Conclusion

Technology used to implement ITS, especially coding of analog video, has advanced significantly over the last decade. It has allowed for the integration of legacy systems with the new, allowing system operators and administrators to perform their job more effectively and efficiently. Public Safety teams can assess incident conditions at a touch of a button, and dispatch response team more appropriately. Transportation partners, using the same information or traffic surveillance feeds, can support incident response by clearing the response path or minimizing traffic impacts caused by the incidents. The hybrid analog/digital video solution is an excellent example of how an entity can take a good reliable system and make it work even better. Digital video overlaid on the traditional analog system results in synergies that work to improve work flow efficiencies, homeland security, and economic vitality.